Retroreflective shadowgraphy of clustered rocket nozzles.
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The plume produced by a cluster of four rocket nozzles during start-up and shut down is visualized here by way of retroreflective shadowgraphy. The technique, originally developed by Edgerton (1958), is employed here using the set-up described by Hargather & Settles (2009). This comprises a retroreflective screen (3M Scotchlite™), a xenon arc lamp point source, a PCO.Edge CMOS Digital Camera and a 45° rod mirror. Direct shadowgraphy easily detects sharp refractive disturbances (e.g. shock waves) as it visualizes the Laplacian of the refractive field. Thus, the plume and shock patterns produced by overexpanded rocket nozzles provide a good platform for testing this new tool.

Tests were conducted in the fully-anechoic chamber and open jet facility of The University of Texas at Austin. The clustered rocket nozzles comprise four subscale, high area ratio rocket nozzles with thrust-optimized parabolic contours. These nozzles are truncated and aerodynamically scaled replicas of the RS-25 engine that will power NASA’s upcoming Space Launch Vehicle (SLS). These nozzles undergo various operating states as described by Donald et al. (2014). In particular, the internal flow transitions from a free shock separated state (FSS) to a restricted shock separated state (RSS) and an “end effects regime” where the RSS flow returns back to FSS flow prior to flowing full. These transition points are known to cause both lateral and acoustic loads that can damage the space vehicle and payload. The objective of the study was to produce a direct link between the acoustic loads registered in close vicinity to the cluster of rockets to the events in the flow visualized using this shadowgraphy technique.